Overview of Biodiesel Production from Algae in Nigeria and Some Developing Countries

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Abstracts:

Presently the world's energy needs are met through non-renewable resources such as petroleum, natural gas and coal. Since the demand and cost of petroleum based fuel is growing rapidly, and if the present pattern of consumption continues, these resources will be depleted in few years. Hence, efforts are being made to explore alternative source of energy. An alternative fuel must be technically feasible, economically competitive, environmentally acceptable and readily available. Biodiesel is found to be environmentally friendly, non-toxic and biodegradable. The raw materials being exploited commercially by the developed countries constitute the edible fatty oils derived from rapeseed, soybean, palm, sunflower, coconut, linseed, etc. Use of such edible oil to produce biodiesel in Nigeria and some developing countries is not feasible in view of a big gap in demand and supply of such oils. However, there are several non-edible raw materials that can be used to place such edible fatty acid oil, such as algae, which could be utilized as a source for production of biodiesel. Therefore, this paper provides an overview of the biodiesel production from algae in Nigeria and some developing countries.

Keywords: Alternative fuel, Developing Countries, Jatropha, Micro and Macro Algae, Trans -esterification**.**

1. Introduction

Energy supply in Nigeria and some of the developing countries is not meeting the demand for it, resulting in poor living condition, impediment to productivity and very slow growth of the economy, amongst other consequences. Petroleum products make substantial contribution to the energy supply situation but with challenges including that, it is a fossil fuel (finite resource), require advanced and imported technology, sabotage, environmental unfriendliness and management issues. Integration of Renewable Energy resources in the energy mix would help in ameliorating the energy crises in the developing countries and seriously reduce the environmental unfriendliness of the fossil fuel [1].

In recent times, there has been renewed interest in the production and development of renewable energy sources. This can be seen from the investment of huge sum of money by various government and agencies around the world. Renewable energy production and development will help diversify agricultural activities, thus in a quiet way supporting agricultural mechanization. It provides the platform to create more jobs, thus empowering the rural people. Most importantly, the production of fuel from renewable energy sources will help Nigeria and the developing countries to curtail the environmental

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consequences emanating from the exploitation of fossil fuel. It will also help in achieving zero net carbon (IV) oxide balance and improvement in urban air quality [2].

The various alternative renewable energy resources include; wind energy, solar energy, hydro energy, geothermal energy, fuel-cell energy, bio-ethanol, and biodiesel. The use of biodiesel is part of sustainable eco-solutions. Biodiesel is biodegradable when compared to fossil fuels. The use of biodiesel is necessary since most of the means of transportation is through diesel engines. The use of edible oil to produce biodiesel in the developing countries is not feasible in view of a big gap in demand and supply of such oils in developing countries. However, there are several non-edible raw materials that can be used to replace such edible raw materials, such as algae, which could be utilized as a source for production of biodiesel. Algae as a raw material in biodiesel production possess several attractive characteristics such as [3];

- By virtue of their relatively small sizes, microalgae can be easily chemically treated.
- Algae can be grown under conditions which are unsuitable for conventional crop production.
- Microalgae are capable of fixing CO2 in the atmosphere, thus facilitating the reduction of increasing atmospheric CO2 levels, which are now considered a global problem.

2. MICROALGAE: Microalgae are usually microscopic, prokaryotic or eukaryotic, and uni- or pluri-cellular organisms. Among the photosynthetic organisms, microalgae are the most efficient in the absorption of CO2 and their growth is directly related to the reduction of GHGs, since they require large quantities of CO2 as carbon source [4]

3. BIODIESEL

Biodiesel refers to a non-petroleum-based diesel fuel consisting of long-chain alkyl (methyl, ethyl or propyl) esters. Thus, the word “bio” refers to a biological source in contrast to the petroleum-based-fuel. Biodiesel is made by chemically-reacting lipids, typically vegetable oil or animal fat (tallow), and alcohol. It is a clean burning renewable fuel made through a chemical process which converts oils and fats of natural origin into fatty acid and methyl esters (FAME) [5] (Smart Fuels LLC, 2009)

3.1 SOURCES OF BIODIESEL

Sources of biodiesel was categorically divided into four main classes thus, Edible sources, Non-edible sources, Animals source and other sources such as Algae, Bacteria, Fungi etc. Table 1 and 2 present the different sources of oil used in producing biodiesel and comparison of oil yield between

microalgae and some other sources of biodiesel.

Table1: Potential sources of biodiesel

Crop	Oil Yield (L/Acre)
Corn	68.13
Soybean	181.68
Sunflower	386.07
Rapeseed	480.69
Canola	495.83
Jatropha	788.33
Oil palm	2403.47
Microalgae	19000-57000

Sources: Christi, 2007.

3.2 SIGNIFICANCE OF ALGAL BIODIESEL

There are many advantages to using algae-based biofuel.

3.2.1Algae-based fuel is has a lot less of an impact on the environment. When the algae are growing, it actually requires CO_2as a reactant to grow instead of the huge output of CO_2produced by the burning of petroleum products, plus algae have the highest rate of consumption of CO_2 among the plants. It is easy to say that growing more algae will have better impact to the environment as it will reduce the CO_2.The algae growing facilities could be situated around power plants and the CO_2that is being produced routed directly to the algae so that it can grow and produce oxygen. A coal power-plant flue gas, which contains about 10 to 30 times as much carbon dioxide as normal air, can be cleaned by this method [8], [9].

4. ALGAE OIL EXTRACTION

Oil extraction from algae is a hotly debated topic because the process is one of the very costly processes which can determine the sustainability of algae-based biodiesel. In terms of the concept, the idea is quite simple: Harvest the algae from its growth medium (using an appropriate separation process), and extract the oil out of it. Extraction can be broadly categorized into two thus; Mechanical and Chemical Methods:

4.1 MECHANICALMETHODS:

The simplest method of extracting oil from algae is mechanical crushing. Since different strains of algae vary widely in their physical attributes, various press configurations (screw, expeller, piston, etc) work better for specific algae types. Usually mechanical crushing is used in conjunction with chemicals. The mechanical methods are further classified into: Expression/Expeller press and Ultrasonic-assisted extraction [10].

- Expression/Expeller press: Algae is dried it retains its oil content, which then can be "pressed" out with an oil press. Since different strains of algae vary widely in their physical attributes, various press configurations (screw, expeller, piston, etc) work better for specific algae types. Many commercial manufacturers of vegetable oil use a combination of

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mechanical pressing and chemical solvents in extracting oil.

- Ultrasonic-assisted Extraction: Ultrasonic extraction, a branch of sonochemistry, can greatly accelerate extraction processes. Using an ultrasonic reactor, ultrasonic waves are used to create cavitation bubbles in a solvent material, when these bubbles collapse near the cell walls, it creates shock waves and liquid jets that cause those cells walls to break and release their contents into the solvent.

4.2CHEMICAL METHODS:

Algal oil can be extracted using chemicals such as Benzene and Ether, algal oil can also be separated by hexane extraction, which is widely used in the food industry and is relatively inexpensive. The downsides to using solvents for oil extraction are the dangers involved in working with the chemicals. Care must be taken to avoid exposure to vapors and direct contact with the skin, either of which can cause serious damage. Chemical methods include: Hexane Solvent extraction, Soxhlet extraction and Supercritical fluid Extraction [11].

- Hexane Solvent extraction: Hexane solvent extraction can be used in isolation or it can be used along with the oil press/expeller method. After the oil has been extracted using an expeller, the remaining pulp can be mixed with cyclo-hexane to extract the remaining oil content. The oil dissolves in the cyclo-hexane, and the pulp is filtered out from the solution. The oil and cyclo-hexane are separated by means of distillation. These two stages (cold press & hexane solvent) together will be able to derive more than 95% of the total oil present in the algae.
- Soxhlet Extraction: Soxhlet extraction is an extraction method that uses chemical solvents. Oils from the algae are extracted through repeated washing, or percolation, with an organic solvent such as hexane or petroleum ether, under reflux in special glassware.
- Supercritical Fluid Extraction: In supercritical fluid/CO2 extraction, CO2 is liquefied under pressure and heated to the point that it has the properties of both a liquid and a gas, this liquefied fluid then acts as the solvent in extracting the oil.

5. BIODIESEL PRODUCTION

The most common process of converting oil extracted from algae to biodiesel is Trans-esterification also called alcoholysis, this process convert oil in to biodiesel in the presence of catalyst.

5.1TRANS-ESTERIFICATION PROCESS

Trans-esterification (also called alcoholysis) is the reaction of a fat or oil with an alcohol to form esters and glycerol, the equation of the reaction is presented in figure 1.

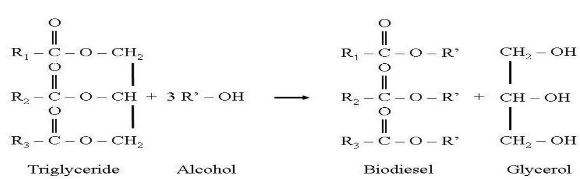

Figure 1: Trans-esterification Reaction

6. Prospects of Algal Biodiesel

In the July 20, 2009 in an issue of Chemical and Engineering News it was reported that ExxonMobil is investing as much as $600 million to partner with Synthetic Genomics Inc. (SGI) in the development of algae derived biofuels. J. Craig Venter, a well-known pioneer in genomics research, is cofounder of SGI [12]. The money invested by ExxonMobil will be spent over a period of five to six years on research and development of algal derived Biofuel.

6.1 Nigeria:

Government of Nigeria has had discussions with top companies from Belgium and Israel for the possibility of undertaking algae biofuel project. Representatives from two companies, Actiview Solutions from Belgium and Univerve Ltd from Israel and top officials from the Nigerian government were a part of the discussion. The discussion was focused on making Nigeria, one of the global suppliers of biofuel, animal feed and food supplements produced from algae. The two companies are seeking the Nigerian government's approval to establish a Microalgae-to-Biofuel Technology Demonstration and Educational Centre in the Lagos State of Nigeria. According to the companies, the Center will be the foundation for establishing commercial scale algae farms in Nigeria.

According to Univerve's CEO Zuckerman, the project will have the capability to ac t as a major driver for the agricultural sector of the country and the final location will be decided later based on the local conditions and availability of water. Taitler, the Managing Director of Actiview opined that the project can act as the catalyst to upgrade Nigeria's economy and added that the company has already secured the endorsement of the African Development Bank and the Belgian Investment Company for Developing Countries as development partners for the proposed algae-biofuel project [13].

6.2 CHINA:

China has started the promotion of its algae based energy since year 2005. The fundamental research on energy microalgae in China has a strong scientific and technological base. Various Universities and Research Institutes are undertaking large numbers of national and provincial level research projects on microalgae classification, breeding and preservation technology. For example:

- Microalgal Hydrogen Production at the Dalian Institute of Chemical Physics (CAS)
- Microalgal Oil production at Ocean University of China
- Tsinghua University and other Institutions have much more research basis.
- ENN Group Co., Ltd. has been developing technology to use microalgae to fix CO2 and then to produce biofuel.
- Marine microalgae bioenergy projects have been established in Shenzhen, Guangdong in 2008. The main objective of the project was the cultivation of diatoms to fix CO2 from flue gas, later on the diatoms were harvested and used for biodiesel production.

- In 2009, CAS and China Petrochemical Corporation (Sinopec Group) decided to develop algae biodiesel technology together. It was expected that an outdoor pilot plant will be operational in about 2015 and a 10,000 ton industrial demonstration unit would be set up in the near future. However, lots of algae breeding work is still in the research and development stage and strains are not qualified for industrialization at present.

From the commitment of research Institute and chemical companies of china we can concluded that, algal biodiesel would be one of the renewable energy source in china in the near future [14].

6.3 INDIA

A National Algal Biofuel Network has been launched in 2008-09 with participation of 12 national laboratories/ institutions/ universities and industries focusing on collection and characterization of algal strains from different ecological niches and deposition of same in 3 repositories, Development of different production systems, Improved algal strains for more oil/lipid content. And also three (3) National Repositories have been set up for depositing algal collections:

- Marine: Bhartidasan University (400 marine cyanobacteria, 50 characterized)
- Brackish water: IMMT, Orissa (150 species collected, 17 submitted) Institute of Minerals and Materials Technology Brackish Water Green Algae Culture Collection Centre (Eastern Zone)
- Fresh Water: IBSD, Imphal (400 unialgal strains) Institute of Bioresources and Sustainable Development (IBSD)

A research work in India has fuelled a Chevrolet diesel tavera on a 20 percent biodiesel blend made from marine microalgae and the test drive recorded a mileage of 12.4 km better than the 10-11 kms recorded by diesel run SUV's. The project was part of the New Millennium India Technology Leadership Initiative (NMITLI) with researchers from the Ministry of Earth Sciences (MoES) and Council of Scientific and Industrial Research (CSIR). The aim now is to run the test vehicle on B-100 (neat biodiesel) marine micro algae biodiesel and evaluate economic viability.

Various universities and research institutes undertaking research on algae fuel include:

University of Madras, Centre for Advanced Studies in Botany

Rengasamy and his team from University of Madras have successfully cultivated Botryococcus braunii in open raceway pond without any contamination. Major focus of this research group is on marine algae for biofuels, CO_2 cycling, production of value added products from algae.

Central Food Technological Research Institute (CFTRI), Mysore

Ravishankar and his team from Plant Cell Biotechnology Department are carrying out extensive work on isolation and characterization of hydrocarbon producing micro alga Botryococcus braunii from Indian waters.

Indian Agricultural Research Institute, Division of Microbiology
Dolly Wattal Dhar, Radha prasanna and their research team –Algae Biofuel.

University of Delhi, Department of Botany
Dinabandu Sahoo and team are working on algae biofuels and CO2 cycling [15].

Companies that will start large-scale projects on algae fuel include:

- Indian Oil and Petro algae
- Teri and ONGC
- Hydrolina Biotech Pvt ltd.
- Bio Max
- Enhanced Biofuel.

7. Conclusion

Micro algal farming has the potential to be combined with flue gas CO2 mitigation and wastewater treatment. It can also use seawater as a medium when marine micro algal species are utilized which mitigates the problem of freshwater shortages. In addition, there is much potential for cost savings when the production of novel products for use in medicine, food, and cosmetics are coupled with the production of biofuels (16). Technological developments which include advances in photo bioreactor design, microalgal biomass harvesting, drying and other downstream processing technologies are important areas that need to be addressed in order to effectively implement the use of biofuel from algae as a replacement for fossil fuels. Algal biodiesel has prospects in developing countries such as China, India, Nigeria etc, but research of algal as a source of biofuel is lacking among our Universities and Tertiary Institutions compared to china and other developing country.

8. Recommendation

1] Government should create Algae for Biodiesel Research Center under Energy Commission of Nigeria to facilitate R and D in Algae plantation, extraction and biodiesel production.

2] Petroleum and Refining Industries should use algal farm to serve as GHGs mitigation option, since algae require huge amount of CO2to grow.

3] Niger Delta Development Commission should provide algae species for rural farmers, since algae can grow well on oily water and hydrocarbon polluted soil

4] Nigerian National Petroleum Cooperation should enforced the provision of algae farm by the oil companies in every operational and non-operational oil field of the country to reduced CO2 emission, since the government is not ready to enforced zero gas flaring in the Niger/Delta region.

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